*Nigerian Journal of Technology (NIJOTECH)*
*Vol. 32. No. 2. July 2013, pp. 170-183*

*University of Nigeria, Nsukka, ISSN: 1115-8443*
*www.nijotech.com*

# THE INFLUENCE OF THE URBAN TRANSPORT SYSTEM IN JAVA ON CITY FUEL CONSUMPTION

**M. Handajani**
DEPARTMENT OF CIVIL ENGINEERING, SEMARANG UNIVERSITY, INDONESIA
E-mail: hmudjiastuti@yahoo.co.id

**Abstract**
***The system of city transportation and city typology in Central Java affects the fluctuation of fuel consumption. The population size, number of private motor vehicles, RGDP (Regional Gross Domesic Product), number of motorcycles and road length have high correlation with fuel consumption. The higher the population size, the number of private motor vehicles, the number of public passenger vehicles, RGDP, the number of motorcycles and the road length are, the higher the fuel consumption in the city will be. The higher the number of public bus/ the number of public vehicles is, the lower the fuel consumption in the city will be. The population size has low correlation with fuel consumption/capita. Higher population size does not always reduce fuel consumption/capita.***

***Keywords****:* correlation, fuel, city, transportation, system.

## 1. Introduction

The increase in the possession and use of private vehicles has caused some impacts: traffic jam, the use of space, environment conservation (exhaust emission, air pollution, energy resource exploitation). Transportation experts are very concerned about the consumption and the increasing scarcity of fuel stock. Transportation sectors spend the highest consumption of more increasingly scarce unrenewable fossil fuel. It is therefore necessary to efficiently use the fuel. City transportation system is influenced by: human beings, goods, vehicles, roads, and management. Fuel consumption is also influenced by land use, population size and population density [1]; [2]; [3], transportation system [4], including the road length [5][3], number of vehicles [6]; [5];[7];[8];[9], the behavior of road users [9], road condition [9], road network patterns [4]; [10].

Data transportation system of the city and the city typology obtained from the Central Bureau of Statistics and fuel consumption data obtained from the office of Pertamina (2007-2008). Cities studied were all cities in Java, Indonesia: 27 cities, 5 metropolitan cities, 4 big cities and 13 towns, not the city of Jakarta, not the district.

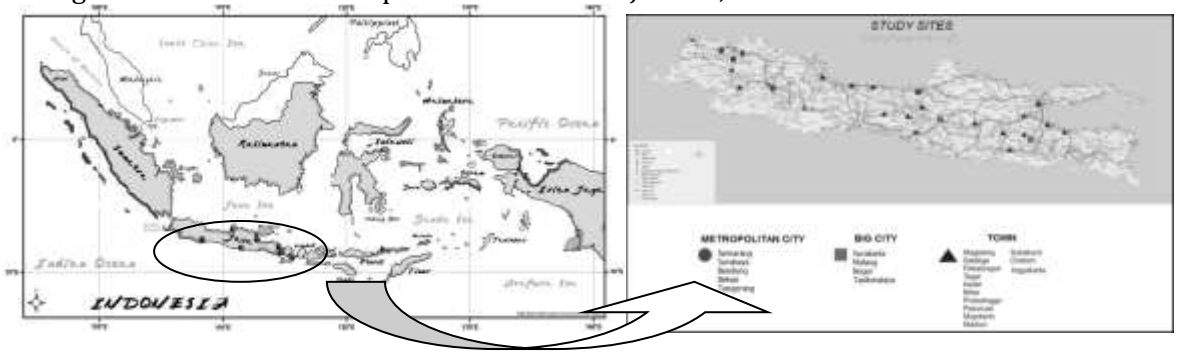



*PLATE 1: Research Sites*

## 2. Literature Review

An energy resource used by the transportation sectors in Indonesia is fuel. Transportation sectors are very dependent on this type of fuel and take up around 50% of all world fuel consumption. Road transportation constitutes around 80% of all transportation sector consumption. Compared with that in 1990, in 2000 the fuel consumption by world transportation sector rose by 25%, and is projected to be 90% until 2030 [11]. The national economic growth increases the possession and use of private motor vehicles in the city areas. The possession of private motor vehicles rises dramatically compared with public vehicles, then consequently increases the fuel consumption. In America (1970–1995) there was a gap between fuel production and the demand of fuel for transportation. This is worrying because the transportation sector still depends on the more increasingly scarce unrenewable fossil fuel. The increasingly less supply affects the rise of the fuel price, and further affects the national social economic condition. Some governments from developing countries, e.g. Nigeria have to provide subsidy to enable the people to buy the fuel. Environmentally-friendly transportation is strategic because the land use is integrated with the transportation, so minimizing the transportation cost, reducing exhaust emission and reducing the fuel consumption [12]. This sub-transportation sector should be given special attention in various policies, planning, and research. According to [13], the fuel consumption for each type of vehicles is different.

## 3. Analysis

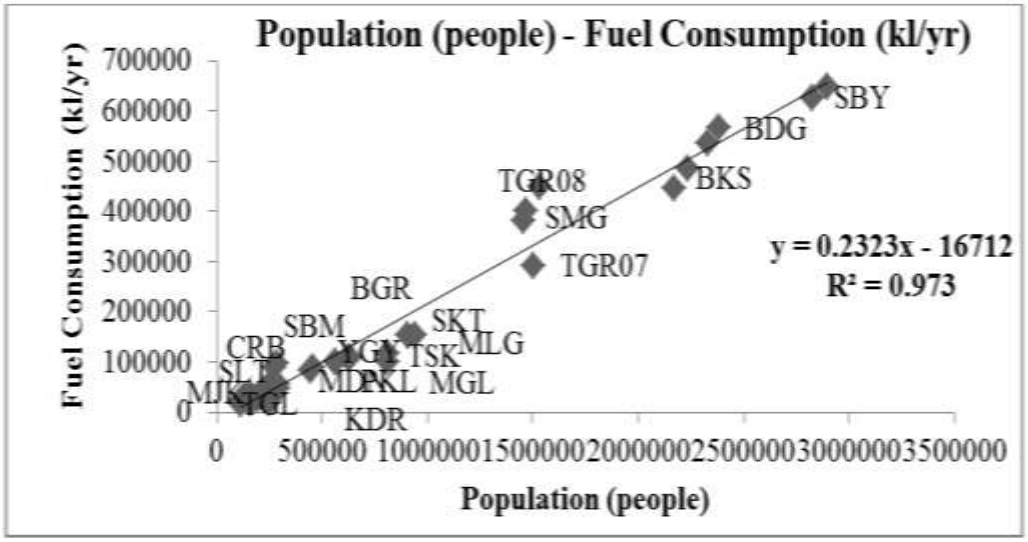
### 3.1 *Relationship between Population Size and Fuel Consumption*

People are highly mobile in conducting daily activities, both within and out of town. The population size in the city during the day is higher than that during the night because during the day many people from out of the city conduct their daily activities in the city. The bigger the population of the city is, the bigger the population size of those who enters the city to conduct their daily activities. The population size and mobility depends on the attractiveness and functions of the city. The transaction of fuel for transportation carried out in the petrol station never discriminates consumers based on their residence and use. Therefore, the variable of population size (local and non-local) and traffic volume (local and non-local) is importantly taken into consideration in the provision of petrol stations. This condition meets [14] that there is a relationship between fuel consumption and population size. [5] Suggests that fuel consumption is closely related to the population size. Therefore, it is hypothesized that the bigger the population size of the city is, the bigger the fuel consumption will be. Cities in Java show a strong linear relationship between population size and fuel consumption. The population growth is correlated with fuel consumption. The bigger the population size is, the bigger the fuel consumption will be. Surabaya has the biggest population size and the highest fuel consumption. Mojokerto has the smallest population size and the lowest fuel consumption. The fuel consumption in Sukabumi does not reflect its population size living in the city, but it is very much influenced by the non-local population size, particularly the population nearby, that is the population of Sukabumi Regency.

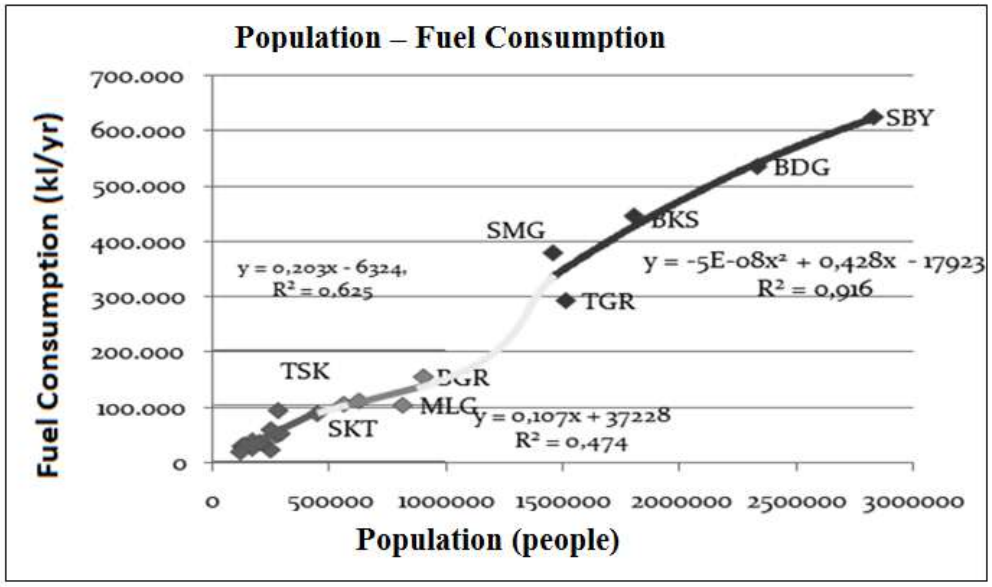
Figure 1 shows a linear relationship between the population size and fuel consumption and the gradient of the population size and the fuel consumption. Medium-size cities and big cities are at the bottom left position, the population size is low, the fuel consumption is low ($R^2$ 0.862). Metropolitan cities are at the top right position, the population size is high, and the fuel consumption is high ($R^2$ 0.973).

### *3.2 Relationship between RGDP (Regional Gross Domestic Product), and Fuel Consumption*:

In [15], it is pointed out that the level of vehicle possession is determined by income. In Asia, according to [16], the economic growth will increase the number of vehicles and population mobility, and will increase the fuel consumption. The people's income significantly influences the transportation behavior. The population with high income has higher and longer mobility than those with low income.



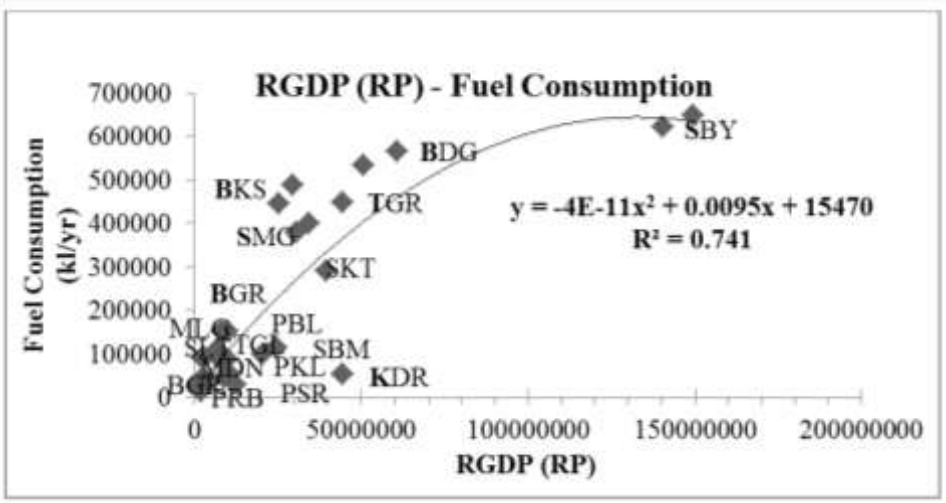

(a)



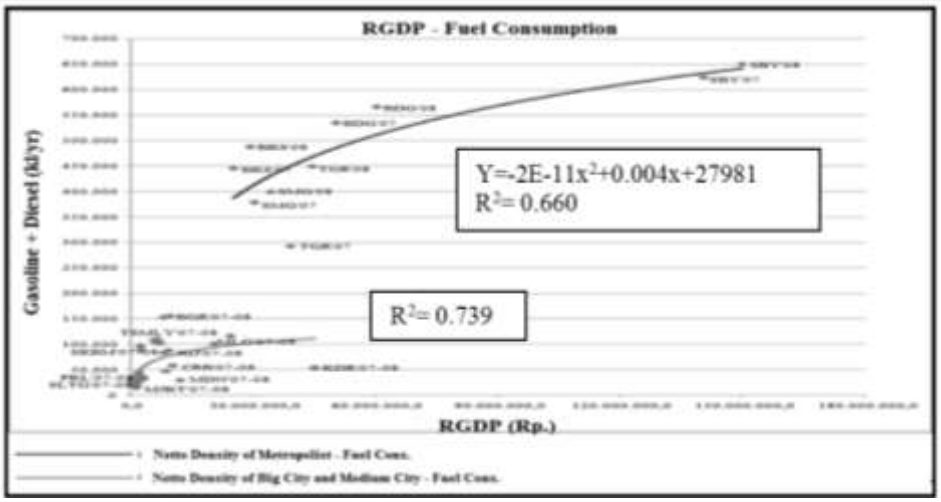

(b)

*Figure 1. The Gradient of Population Size - Total Fuel consumption, Source: [2]*

RGDP based on the existing price corresponds with the fuel consumption, except Kediri, in accordance with the views from APERC Workshop *at the* EWG 30, [17] that an increase of income/capita increases RGDP. The increase of fuel consumption in big and medium-size cities is influenced by the increase of population size. The fuel consumption increases faster than the increase of RGDP. The position of medium-size cities and big cities is at the bottom left corner, RGDP and fuel consumption are low ($R^2$ 0.739). The increase of RGDP of metropolitan cities is faster than that of fuel consumption. The increase of fuel consumption is influenced by the increase of RGDP. The position of metropolitan cities is at the top right side. The RGDP and fuel consumption in metropolitan cities are high ($R^2$ 0.660). The relationship of the current RGDP - fuel consumption/year is adequately significant ($R^2$ 0.741). The relationship of RGDP - fuel consumption/year is presented in Figure 2.




*(a)*




(b)

*Figure 2. The Relationship and Gradient of Current RGDP - Total Fuel consumption kl/year. Source: [2]*

### *3.3 Relationship between Vehicles and Fuel Consumption*

In [15] it is pointed out that the level of vehicle possession is determined by the local population habits, income, facilities and efficient use of public transportation. The people's pattern of travel determines more the possession of vehicles. The number of vehicles (private + public + goods) has a stronger relationship with fuel consumption (petrol + diesel fuel = total), as direct users of fuel, except the relationship between private buses and public buses and fuel consumption and total consumption. The relationship between private buses- diesel fuel consumption and total consumption is relatively strong. The relationship between public buses - diesel fuel consumption and total consumption is very low. This condition is caused by the small number of public buses. In fact, buses greatly influence the amount of fuel consumption.

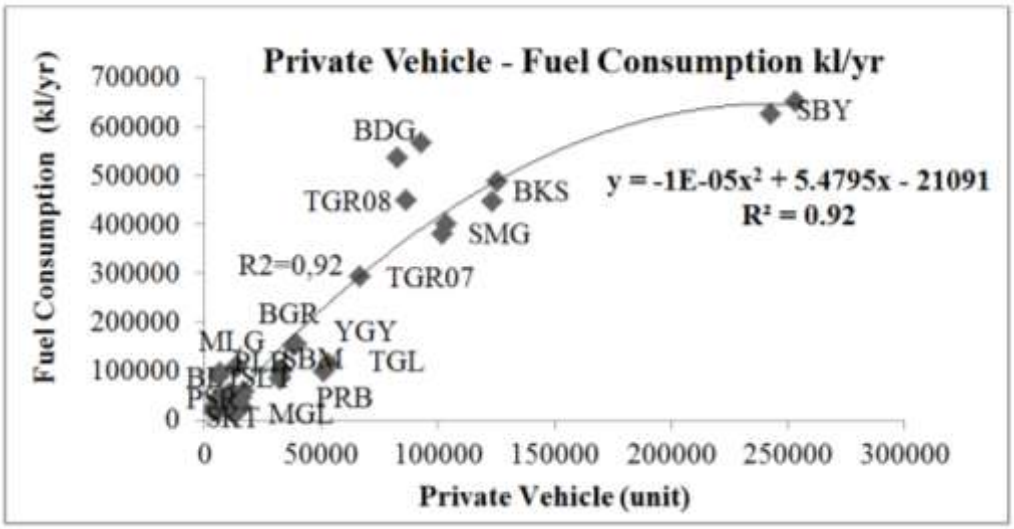
#### *3.3.1 Relationship Between Private Vehicles and Fuel Consumption*

In [6]; [5]; [7]; [8]; [9] suggest that the number of vehicles is related with fuel consumption. [18] Suggests that the fuel consumption for each vehicle needs different fuel km/liter, the length of travel km/day, the need of fuel liter/year. The fuel consumption of private vehicles: 700 liter/year, the fuel for buses: 9780 liter/year, the fuel for motorbikes: 420 liter/year.

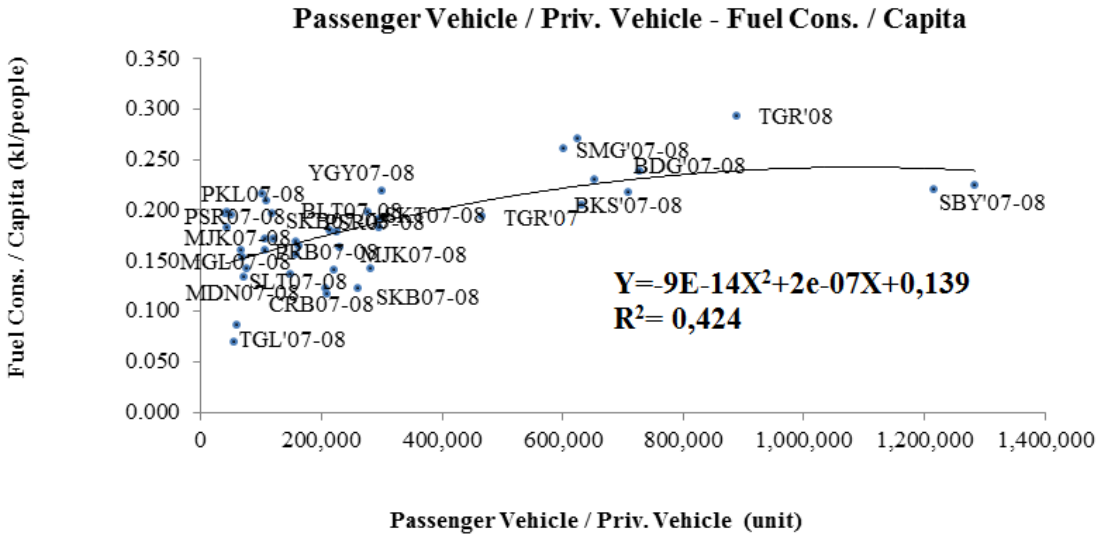
The number of private vehicles corresponds with fuel consumption ($R^2$ 0.92). Surabaya has the highest number of private vehicles, and the highest fuel consumption. Private vehicles in Bandung are less than those in Bekasi and Semarang. Bandung has the high number of

public transportation (5.986 unit), high net population density (22,426.87 people/km$^2$), high population size (2,329,928 people), and high fuel consumption. The very high number of vehicles in Bandung on Saturday, Sunday, holidays, increases the fuel consumption. Tegal has the lowest private vehicles, and low fuel consumption. The increase of the percentage of private vehicles will increase the fuel consumption/population. The higher the RGDP/population is, the higher the percentage of the number of passenger vehicles will be and the higher the fuel consumption will be.

The relationship between the private vehicles – the fuel consumption/population is rather strong ($R^2$ 0.424). The percentage of the number of vehicles in Java is almost the same as the percentage of the number of vehicles in Indonesia. According to [19], the number of vehicles for passenger vehicles, buses, trucks and motorbikes all over Indonesia is 15% of passenger vehicles, 3.64% buses, 8.39% trucks, 72.63% motorbikes. This study is expected to represent the conditions in Indonesia. The relationship between private vehicles - fuel consumption and the relationship between private vehicles -fuel consumption/capita is presented in Figure 3.

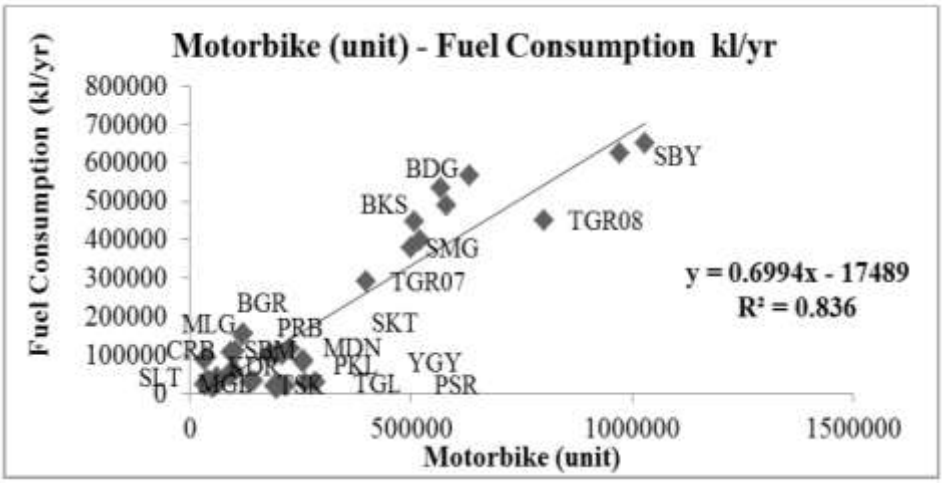



(a)

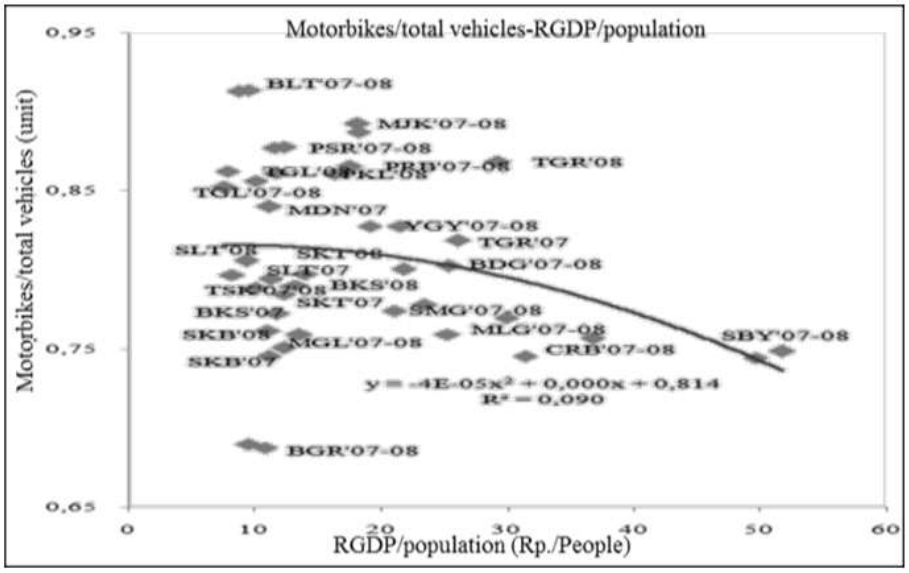



(b)

*Figure 3. Relationship between private vehicles - fuel consumption (kl/year) and Relationship between private vehicles/private vehicles-fuel consumption/capita, Source: [2]*




(a)




(b)

*Figure 4: Relationship between motorbikes (unit) - total fuel consumption (kl/year) and Relationship between motorbikes/total vehicles-RGDP/population Source:[2]*

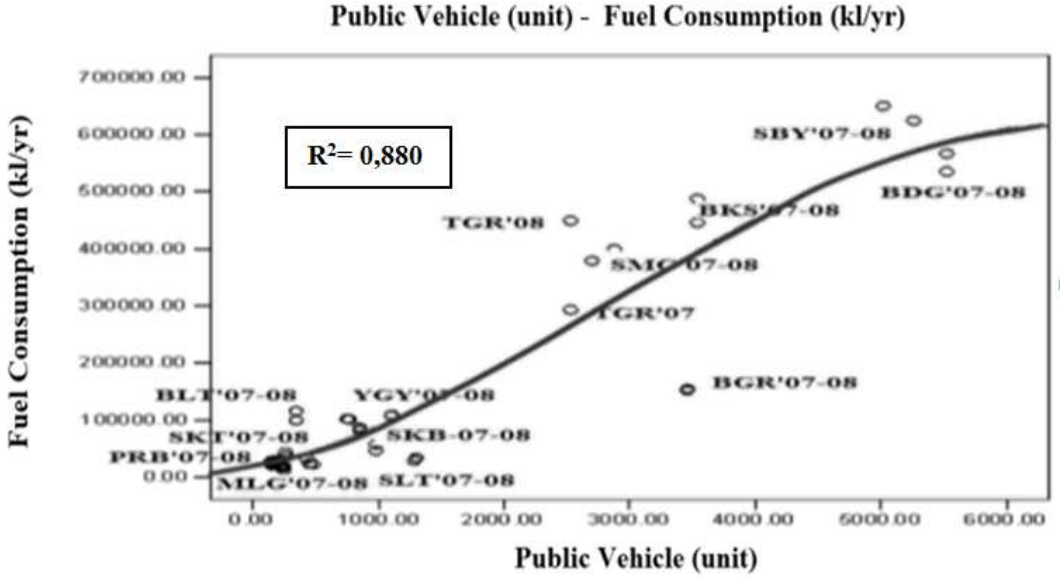
Motorbikes are much more than private vehicles. Fuel consumption/unit of motorbikes is less than fuel consumption/unit of private vehicles. The average percentage of the number of motorbikes in each city is high (>85%). The percentage of the number of motorbikes in Bogor is the lowest (74,82%); the highest percentage is in Blitar (94.79%). There is a strong relationship between the number of motorbikes (unit) - fuel consumption $R^2$ 0.836. Surabaya in 2008 had the most number of motorbikes (1.028.686 unit) and the highest fuel consumption. The lowest number of motorbikes in 2007 is in Sukabumi (32.469 units). Figure 4 shows an increasingly high trend of RGDP/population and the increasingly low percentage of the number of motorbikes ($R^2$ 0.090).

*3.3.2 Relationship between Public Vehicles and Fuel Consumption*

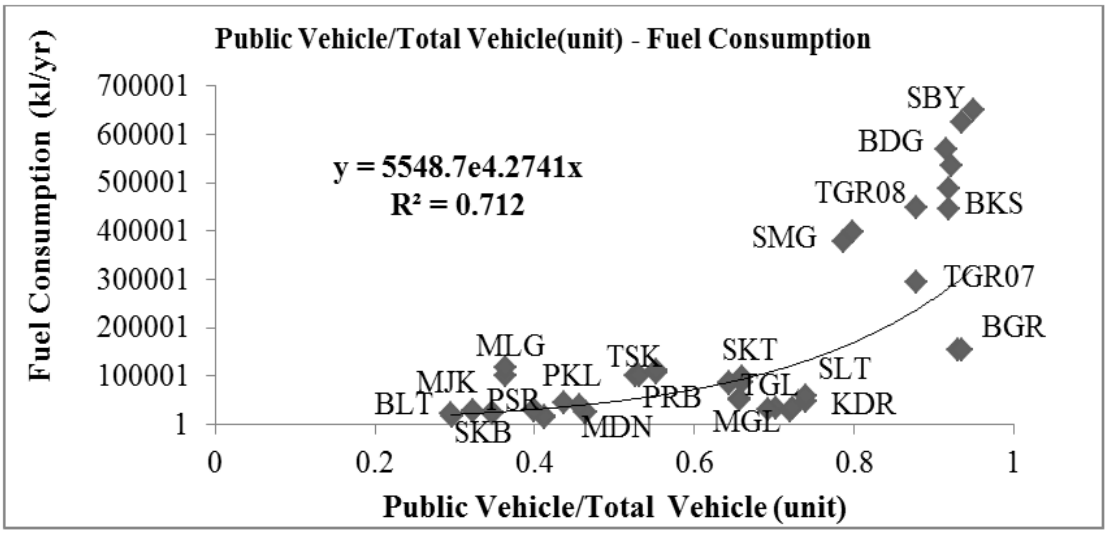
According to [20], the population density in the city should be bigger than 35 people/ha for the people to use public transportation. When big capacity public vehicles are used, the fuel consumption would be lower. In Singapura and Hongkong, public transportation, consisting of MRT and bus ways serves 85% of the population. In Jakarta (Indonesia) the number of public transportation is no more than 10 percent of the number of existing vehicles [21]. The number of public buses and city public

passenger vehicles in Java is only 0.63% of the number of private and public vehicles. [22] Mentions that Bandung has too many public passenger vehicles and high fuel consumption. The fuel consumption for buses is higher than fuel consumption for public passenger vehicles. If one bus replaces 3-5 public passenger vehicles, the fuel consumption and the road density could be decreased. [13] suggests that the fuel consumption per unit of public passenger vehicles is 6,000 liter/year; the fuel consumption per unit of bus is 9,780 liter/year.

There is a strong relationship between the number of public passenger vehicles - fuel consumption ($R^2$ 0.880). Malang has the small number of public passenger vehicles and quite high consumption because there is quite high number of private vehicles in Malang. Surabaya and Bandung have high number of public passenger vehicles and high fuel consumption. There is a strong relationship between public passenger vehicles/total public vehicles - total fuel consumption/year ($R^2$ 0.712) The higher the number of public passenger vehicles/total public vehicles is, the higher the fuel consumption will be. The relationship between the number of public passenger vehicles - fuel consumption and the relationship between public passenger vehicles/total public vehicles - total fuel consumption /year is presented in Figure 5.

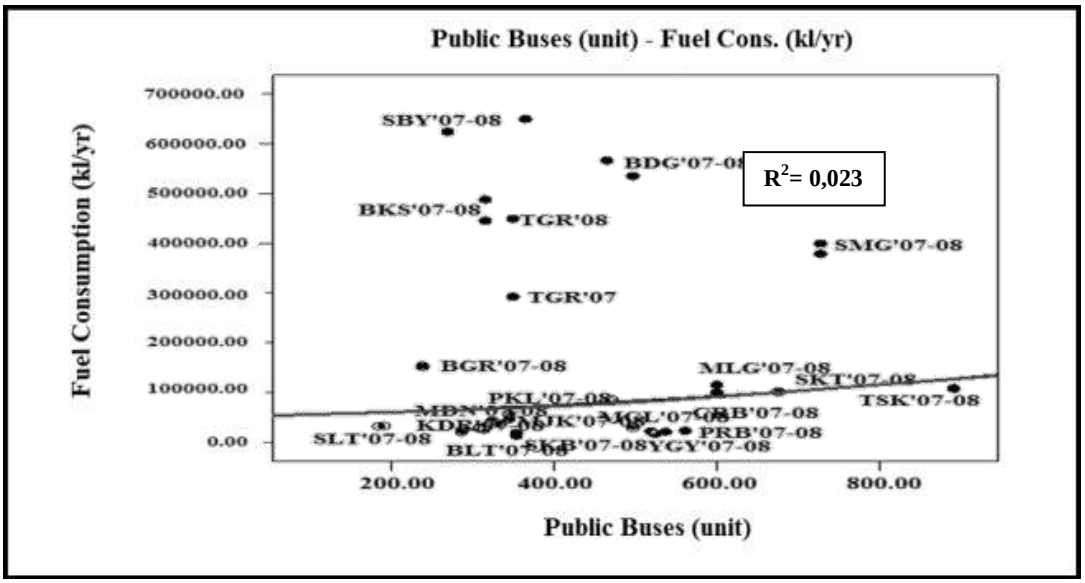



(a)

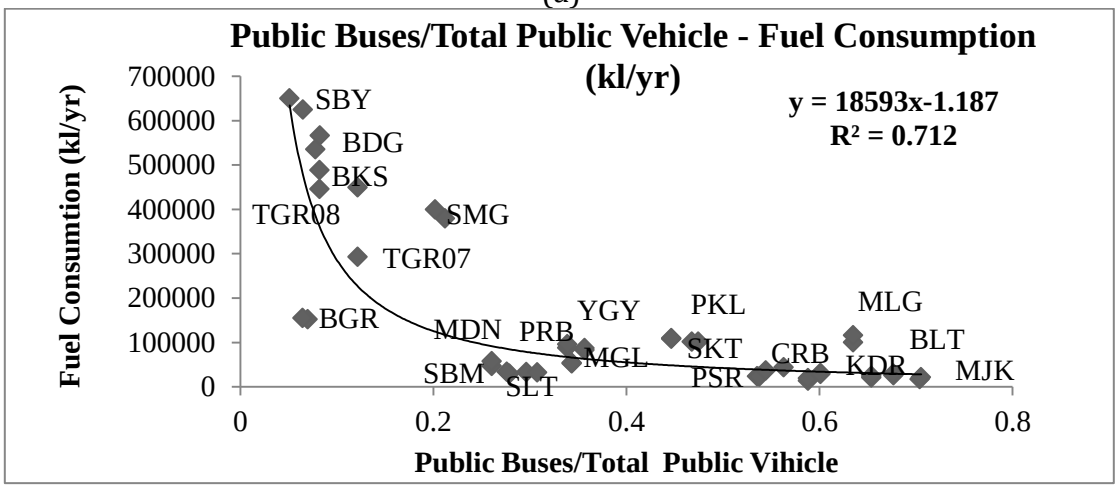



(b)

*Figure 5. Relationship between public passenger vehicles - total fuel consumption (kl/year), Source: [2]*




(a)




(b)

*Figure 6. Relationship between public buses– total fuel consumption and relationship between public buses /total public vehicles - fuel consumption/year Source:[2]*

Figure 6 shows the relationship between the number of buses – the total fuel consumption kl/year and the relationship between public buses /total public vehicles - fuel consumption/year. The higher the number of public buses /total vehicles is, the lower the fuel consumption will be ($R^2$ 0.712). There is no strong relationship between public buses and the total fuel consumption ($R^2$ 0.023). The number of public buses for all cities is very low (9.328 unit) or 0.145% from the total passenger vehicles (6,384,406 unit). [15] mentions that public buses (RTBs-Rapid Transit Buses) should be operated for a city with the population of more than 1 million people. In fact, not all cities in in Java operate RTBs; more public passenger vehicles are operated because there is a problem of replacing public passenger vehicles with buses.

*3.3.3 Relationship between Goods Transport and Diesel Fuel Consumption*

The high number of trucks will increase the fuel consumption. According to [13], the fuel consumption for trucks is the highest (9,500 liter/year) of all vehicles. There is a quite strong relationship between truck-diesel fuel consumption ($R^2$ 0.699). (see Figure 7). The higher the the number of trucks is, the higher the diesel fuel consumption will be.

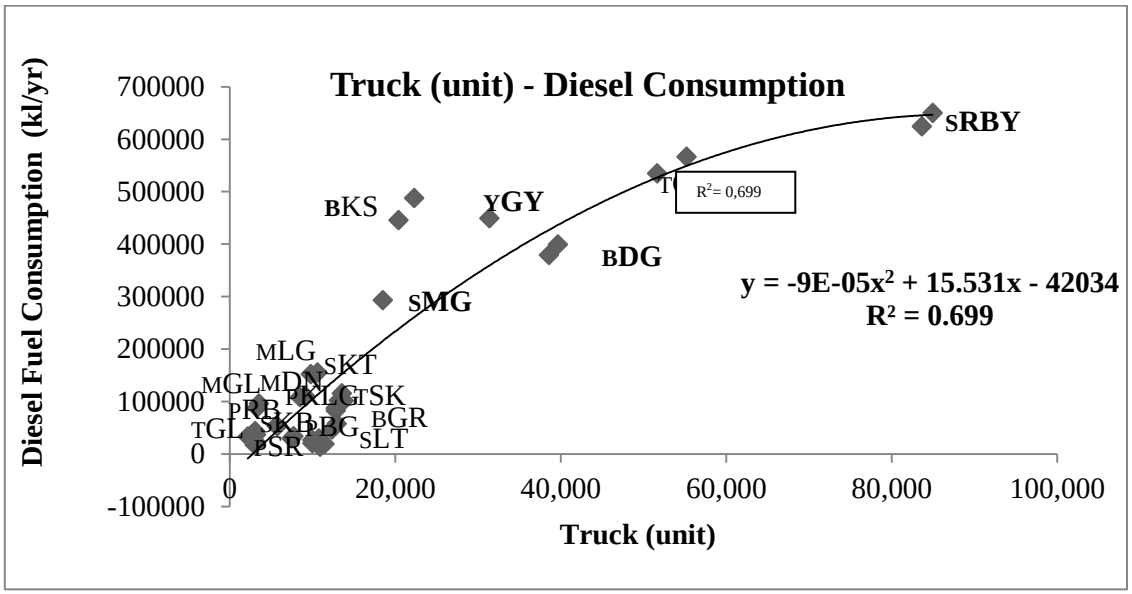
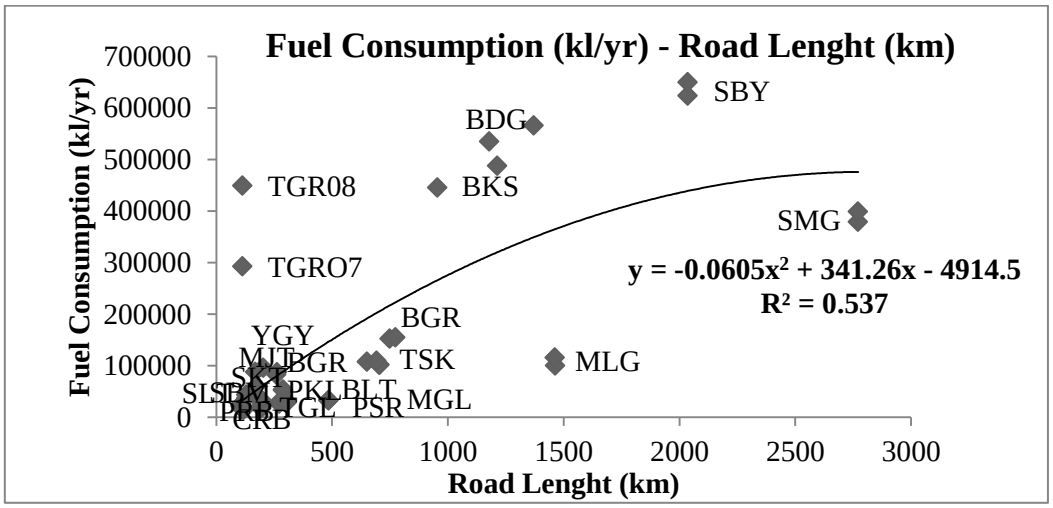



*Figure 7. Relationship between truck – diesel fuel consumption, Source:[2]*

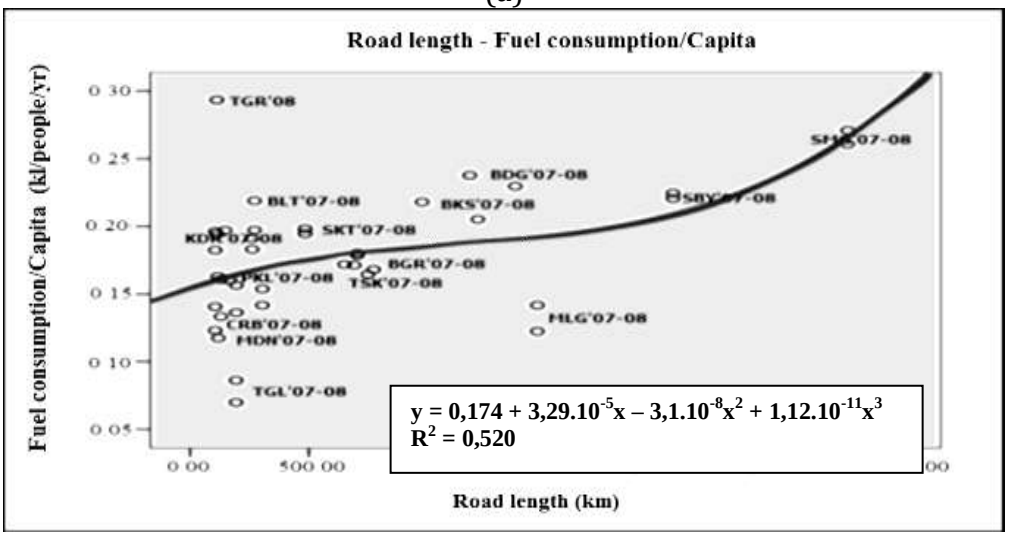
### *3.4 Relationship between Road Length and Condition - Fuel Consumption*

The road length of the cities in Java corresponds with the fuel consumption. According to the study [5] in Palembang, the longer the road is, the higher the fuel consumption will be. There is a relationship between the road infrastructure in the city and the city budget (RGDP). There is a quite strong relationship between the road length - total fuel consumption ($R^2$ 0.537). Surabaya has the longest road because it has wide administrative areas, high developed areas, high population size, high number of vehicles, and high fuel consumption. Semarang has long road, big administrative areas, low developed areas, longer travel, lower population size (than Surabaya). Malang has long road, does not have many vehicles and does not have high fuel consumption. The relationship between the road length – the fuel consumption is presented in Figure 8.

Semarang has the highest fuel consumption/capita (excluding Sukabumi with its anomaly). The high administrative areas and the low percentage of developed areas cause long travel time and quite high population size. There is no strong relationship between the road length – the fuel consumption/capita ($R^2$ 0.520) as presented in Figure 9. According to [8], the road condition influences the amount of fuel consumption. There is a quite strong relationship between good road length condition – the fuel consumption/year ($R^2$ 0.425). The fuel consumption in Semarang and Surabaya is high and the good road condition is high. Tangerang has short good road length condition, high fuel consumption/year because of too many vehicles in that city. Malang has high good road length condition, low fuel consumption because of the small number of vehicles. There is weak relationship between the number of vehicles/road length and the fuel consumption/capita ($R^2$ 0.161) because of the low consumption/population. The total number of vehicles/road length in Tangerang is high because of the high number of vehicles and the short road length.




(a)




*(b)*

*Figure 8: Relationship between Road length - Fuel consumption /Year and Relationship between Road length - Fuel consumption/Capita, Source:[2]*

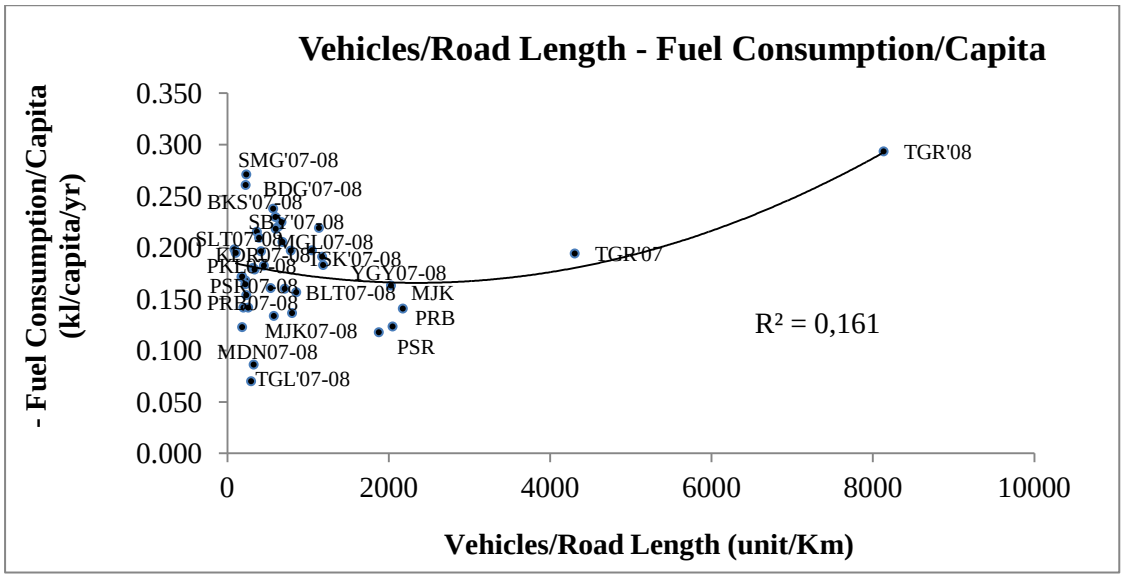


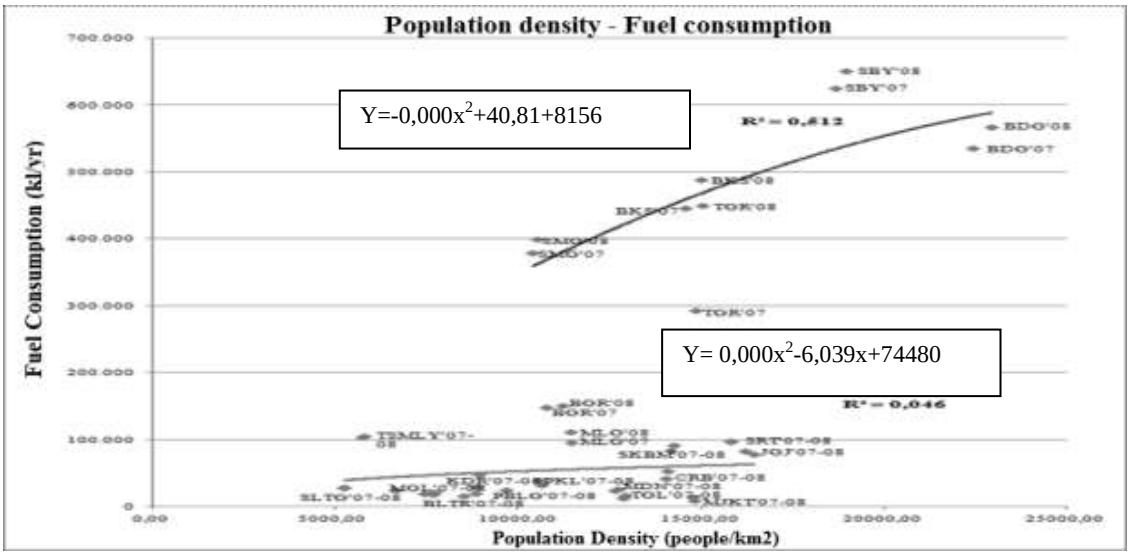

*Figure 9: Good Road Length Condition - Fuel consumption/Capita and Relationship between Vehicles/Road Length - Fuel Consumption/Capita. Source: [2]*

### *3.5 Relationship between Net Population Density - Fuel consumption*

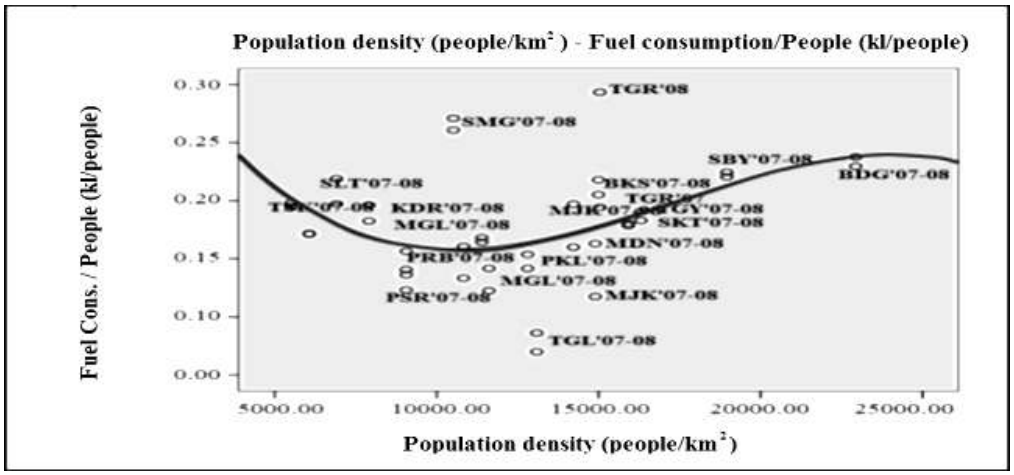
The paper [20] state that the higher population density is, the lower the fuel consumption/capita will be. [15] mention that an increase in the population density will not always decrease the possession of vehicles and will decrease the fuel consumption, but the travel pattern of the population will determine more the fuel consumption. According to [23], the population density has low corelation with the fuel consumption.

The population density in the cities in Java does not always correspond with the fuel consumption ($R^2$ 0.54). The increase in population will not always increase the population density. The developed areas increase horizontally, the travel time remains long, and the fuel consumption increases. The population density increases the fuel consumption, according to [15]. The increase in population in medium-size and big cities does not always increase the population density because the developed areas grow horizontally and the travel time is longer. The population in metropolitan cities will increase the population density because the developed areas reach the administrative areas, the developed areas grow vertically, the travel time is shorter even though the fact shows that the developed areas are not limited within the administrative areas.

Figure 10 shows that the net population density in metropolitan cities goes away from that in big cities and medium-size cities. The fuel consumption in medium-size and big cities is at bottom left position, the net population density is low, and the fuel consumption is low. The fuel consumption in metropolitan cities is at top right position, the net population density is high, and the fuel consumption is high. The increase in the fuel consumption in metropolitan cities is caused by the effect of the increase of RGDP, the increase of fuel consumption of medium-size and big cities because of the effect of the increase in the population size. There is a quite strong relationship between the net density – the fuel consumption/year in metropolitan cities ($R^2$ 0.512). There is a very low relationship between the net density – the fuel consumption/year in big cities and medium-size cities ($R^2$ 0.046). According to [24], the higher the population density of the city is, the lower the fuel consumption/capita will be. This is not the case in the cities in Java, the high population density does not always decrease the fuel consumption/capita. Bandung has very high density and high fuel consumption. According to [25], when the population density is high, the public transportation system is used in the city and people can use public transportation for daily activities and for travelling to their various work places.




(a)




(b)

*Figure 10: Gradient population density – Fuel consumption*

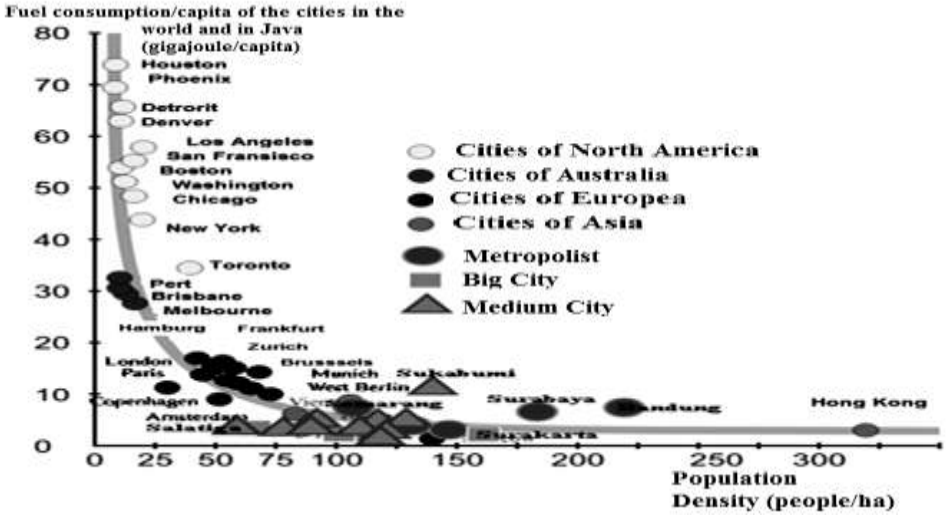



*Figure 11. The Graph of the Relationship between Population density - Fuel consumption/capita of the cities in the world and in Java Resource: [6][26]*

In the cities in Java (Indonesia), the population density is (6,007.54 – 22,936.37 orang/km$^2$). Almost all cities, when included into [6] graphs, are located in the lower position, meaning that the fuel consumption in the cities in Java is lower than the fuel consumption (R=0.195) in the cities in developed countries. The different policies in the city transportation system, availabe facilities and infrastructures and economic conditions (RGDP) influence the different fuel consumption. The fuel consumption in the cities in Asia depends more on the pattern of population mobility, not the population density [1]. The relationship between the population density - fuel consumption/capita in the cities in the world and in Java is presented in Figure 11.

## 4. Conclusion

The effect of the city transportation system on the fuel consumption is as follows:

1. The population size has a strong effect on the fuel consumption.
2. RGDP has a strong effect on the fuel consumption.
3. Private vehicles have strong relationship with the fuel consumption .
4. The higher the number of public passenger vehicles/Total Public Vehicles is, the higher the fuel consumption will be.
5. The higher the proportion of the buses to total public vehicles is, the lower the fuel consumption will be.

6. The higher the number of trucks is, the higher the fuel consumption will be.
7. The longer the road length is, the higher the fuel consumption will be.
8. The higher the high population density is, the higher the fuel consumption will be, different from [25].

## 5. Suggestion

To be efficient fuel consumption, need to use public transport mass, age restrictions on vehicles, using sea of modes for transportation of goods, the compact Land use.

## 6. Acknowledgment

This research was sponsored through Competitive Grant from Directorate General of Higher Education of Ministry of Education and Culture of the Republic of Indonesia 2009.

### References

1. V. Vichiensan, K. Miyamoto, V. Rujopakarn, 2007, *An Empirical Study of Land Use/Transport Interaction in Bangkok With Operational Model Applicaion,* Journal of The Eastern Asia Society for Transportation Studies, Vol. 7, 1250-1265.

2. M. Handajani, 2012, Model Non Linear Konsumsi Bbm Kota Sedang Akibat Pengaruh Sistem Transportasi, The 15th FSTPT International Symposium, STTD Bekasi, November 23-24, 2012.

3. X. Luo, H. Daimon, A.Marimoto, H. Koike, 2007, *A Study on Traffic Behavior on High Income People in Asia Developing Countries,* Journal of The Eastern Asia Society for Transportation Studies, Vol. 7, pp. 1222-1235
4. G. O. Mitchell, 2003, *The Indicators of Minority Transportation Equity (TE)*, Sacramento Transportation & Air Quality Collaborative Community Development Institute.
5. T. Andry, 2003, Estimasi Permodelan Kebutuhan BBM Untuk Transportasi Darat (Studi Kasus Palembang), Program Pasca Sarjana MSTT, UGM, Jogjakarta.
6. K. J. F. Laube, 2002, *Urban Transport Patterns in a Global Sample of Cities and Their Linkages to Transport Infrastructure, Land-use, Economics and Environment.*
7. Hayashi, 1996, *The Process of Motorisation.*
8. Departemen Perhubungan Darat, 2008.
9. Fwa T. F., 2005, *Sustainable Urban Transportation Planning and Development Issues and Chalenges for Singapore.* Dept of Civil Engineering of Singapore.
10. Stead Dominie and Stephen Marshall, 2001, *The Relationships Between Urban Form and Travel Pattern. An International Review and Evaluation*, EJTIR, 1 no 2, pp 113-141.
11. Departemen ESDM, 2004, Konsumsi Energi di Indonesia.
12. H. A Rasyid, M Isnaeni, S. D. Nurjaya, 2003, *Urban Transport and Land-Use Planning Toward The Sustainable Development (Case Study of Bandung Metropolitan Area),* Journal of the Eastern Asia Society for Transportation Studies, Vol 5.
13. B. M. Sidik, 2007. *Analisis Kebutuhan dan Penyediaan Bahan Bakar Minyak di Sektor Transportasi di Propinsi Gorontalo*, Perencanaan Energi Propinsi Gorontalo 2000-2015. Gorontalo.
14. R. Jean-Paul, 2004, *Transportation and The Environment,* Dept. of Economics & Geography Hofstra University, Hempstead, NY, 11549 USA.
15. A. Bertraud. and W. Richardson, 2004, *Transit and Density: Atlanta, The United States and Western Europe,* in Urban Sprawl in Western Europe and The United States, Urban Planning and Environment, Ashgate.
16. P. J. Marcotullio, 2007, *Limited provision of Roads as botleneck on vihecle*, Journal Environment and Pollutan vol.30, no 1, Hunter college CUNY, NY, USA.
17. APERC Workshop at the EWG 30, APEC Energy Future, 2005, *Urban Development and transportation Energy Demand Motorisation in Asian Cities*, Asia Pacific Energy Research Centre, Naoko DOI.
18. J. D. C. Manuel, G. S. Ricardo, N. V. Karl, CM Aura, L. Angelo, 2005, *Development of Emission and Engine Testing Prosedures and Standard Sidecar Design Prototype For Tricycle*, Journal of the Eastern Asia Society for transportation Studies, vol 6, pp 3151-3166.

19. B. Riyanto, K. Pinardi, H. Mudjiastuti., 2012, The Competence of Higher Education Grant

20. Newman, Peter, Kenworthy, and John, 2006, *Urban Design to Reduce Automobile Dependence Opolis* 2(1) winter.
21. DKI Jakarta, 2005, *The Strategical out line scenario of the air quality management in the Provincial area of DKI Jakarta Action Plan for Jakarta Air Quality Management*, The Provincial Government of Special Capital District of Jakarta, Clean Air Program.
22. T. Suryo, 2010, Merancang Transportasi Publik Kota Bandung : Upaya Estimasi pergerakan dan pemilihan moda optimum, ITB, Bandung.
23. D. Naoko, 2007, *Urban Transport Energy Use in the APEC Region Trend and Option,* Asia Pacific Energy Research Centre.
24. J. Kenworthy J., 1999, *Sustainability and Cities*
25. V. Fauchier and P. Merlin, 1994, *High Urban Densities a Solution For Our Cities,* Consulate General of France in Hongkong And French Institute of Town Planning.
26. M. Handajani, 2012, Model Konsumsi Bahan Bakar Minyak (BBM) Akibat Pengaruh Sistem Transportasi Kota di Jawa, Konferensi Nasional Pascasarjana Teknik Sipil 2012, KNPTS, Bandung, 7 December 2012.